Prediction of Equatorial Spread F Based on Assimilation of Daytime GPS Data

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LONG-TERM GOALS

Under ONR grant N00014-03-1-0243 we will explore the value of airglow imagers in the testing of assimilative models of the equatorial ionosphere. We have made data exchange agreements with both the Jet Propulsion Laboratory and the Air Force Research Laboratory in this regard. Our first goal is to verify conditions calculated by the models prior to the breakout of Equatorial Spread F (ESF), a severe ionospheric weather phenomenon. The second goal is to see if data assimilation can be used to predict these conditions and subsequently predict ESF itself. A third goal is to calibrate GPS occultation data using the Arecibo radar and then apply this method to determine the off-equatorial E-region conductivity.

OBJECTIVES

The objectives of the project are:

(1) to develop the software needed to calculate the expected airglow from the equatorial ionosphere using the outputs of ionospheric models;

(2) to compare the model results with the actual airglow;

(3) to use the data assimilation techniques to predict the airglow characteristics and, eventually, ESF;

(4) to use GPS occultations to determine the off-equatorial *E*-region conductivity.

APPROACH

We will work closely with two leading data assimilation modeling groups, one at the Jet Propulsion Laboratory (JPL) and one at the Air Force Research Laboratory (AFRL). Once we verify the airglow diagnostic we will move on to test the assimilation aspects of both models. Finally, we will use those techniques to predict ESF. The airglow system also detects the depletion zones that are so disruptive to communications and navigation systems and hence can be used to check the predictions of severe weather. Concerning GPS, we will first calibrate the COSMIC system using incoherent scatter radar, then apply it to (4) above.

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WORK COMPLETED

We chose April 1/2, 2002 as our first control day (without a Convective Ionospheric Storm/Equatorial Spread F). The airglow observation for the night is presented in Figure 1. Airglow calculations using the output of the International Reference Ionosphere (IRI) have been completed (Figure 2) and compared to the actual airglow observed on December 8/9, 2002. The predicted airglow maximum lies much lower on the horizon as viewed from Maui than that which we observe. This is not surprising since electric fields can create a much higher ionosphere at the equator than IRI predicts. This is one reason ESF occurs!

Figures 3 and 4 show comparisons with JPL's climatological model and assimilative model, respectively, for this date. Clearly, a lot of work needs to be done. Presentations were made at the CEDAR meeting as well as to the Communications and Navigation Outage Forecast System (C/NOFS) science working group concerning our plans.

Figure 5 shows one calibration of the COSMIC GPS occultation experiment, which is quite good. We are exploring the reasons for the discrepancy, using airglow data. Many more passes will be examined.

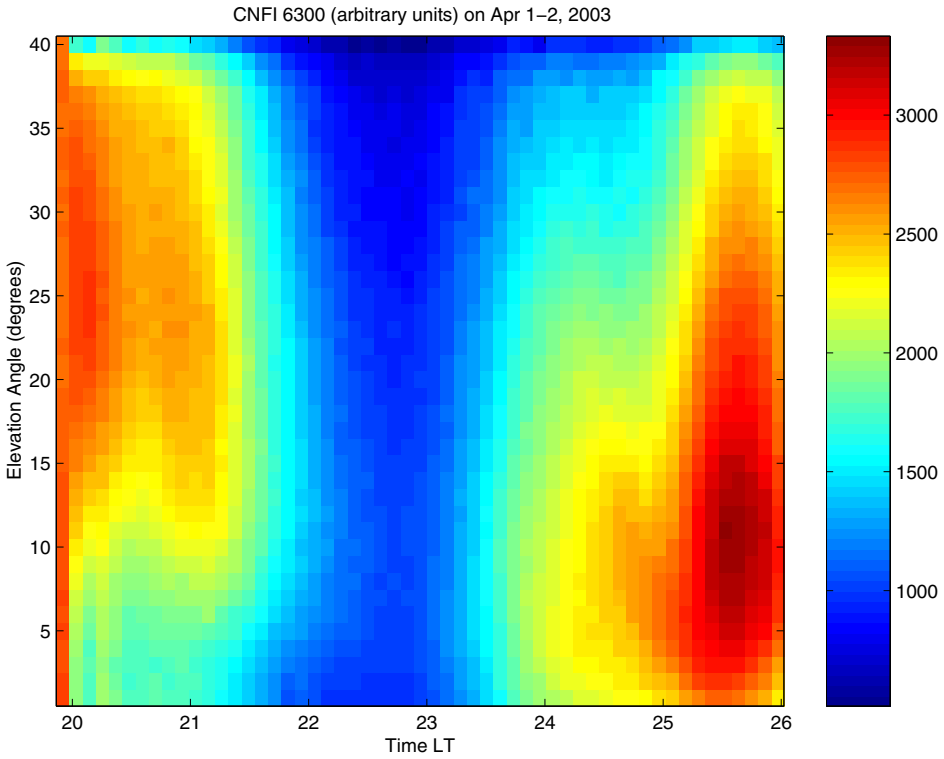

Figure 1. Airglow observations.

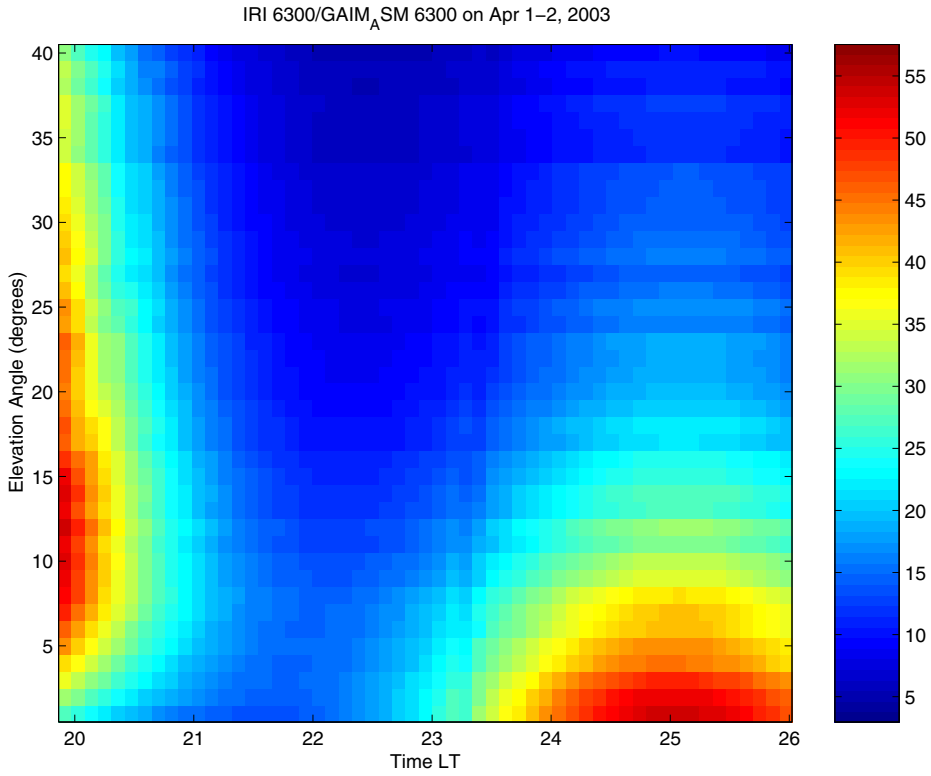

Figure 2. Airglow prediction using IRI.

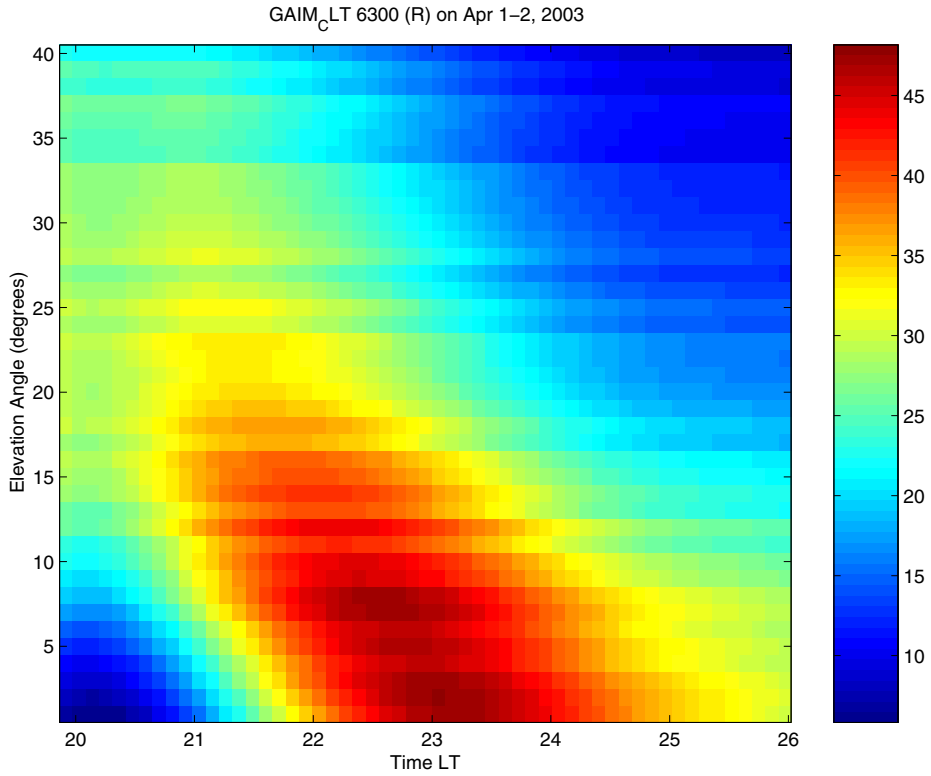

Figure 3. Airglow prediction using only climatology (JPL-GAIMC).

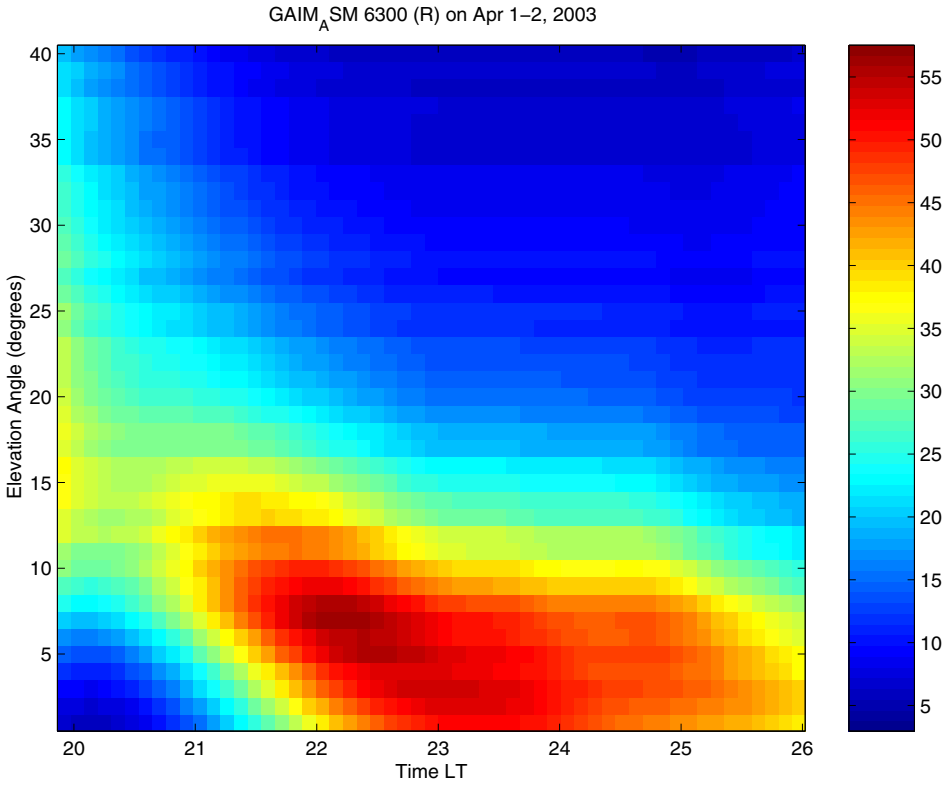

Figure 4. Airglow prediction with assimilation (JPL-GAIMA).

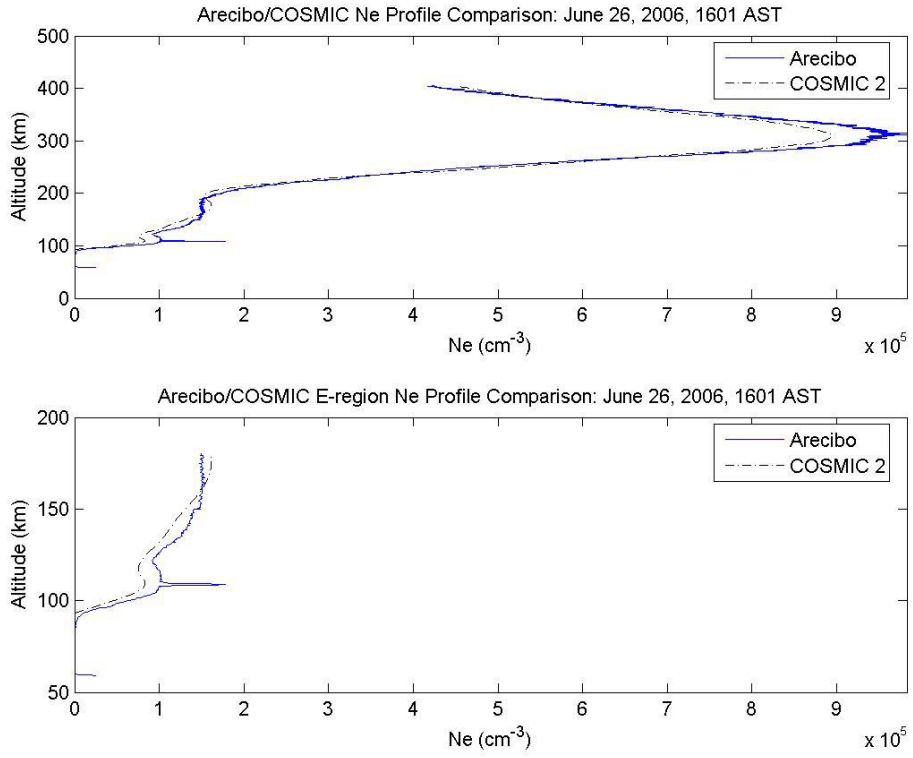

Figure 5. First calibration from the COSMIC GPS occultation experiment.

RESULTS

We have published a *Geophysical Research Letters* article entitled "On measuring the off-equatorial conductivity before and during convective ionospheric storms" [*Kelley et al*., 2004] under this grant and will present our calibration results twice at meetings in 2006. We hope to publish comparisons such as those above with as many as four models: IRI, AFRL, GAIM-JPL, and GAIM-USU.

IMPACT/APPLICATIONS

There is a great need for testing data assimilation methods in ionospheric space weather research. We will do this in one of the most important and severe space weather research areas. We feel that our testing methods will have an impact on the development of both the JPL and AFRL assimilation models. The latter is a crucial component in a major DOD effort to predict communications and navigation outages in the C/NOFS Program. We also have some hope that by assimilating daytime TEC values and satellite electric field patterns we can predict ESF in the post-sunset period. GPS occultations are also to be used for assimilation models. Our calibration work is crucial in testing the validity of these data.

TRANSITIONS

No transitions have occurred as yet but we anticipate that airglow observations and occultation data will play an important role in the development and testing of ionospheric models.

RELATED PROJECTS

None.

PUBLICATIONS

Kelley, M.C., V.K. Wong, G.A. Hajj, and A.J. Mannucci, On measuring the off-equatorial conductivity before and during convective ionospheric storms, *Geophys. Res. Lett*., *31*, L17805, doi:10.1029/2004GL020423, 2004. [published, refereed]

Kelley, M.C., and M.J. Nicolls, Penetration of solar wind and magnetospheric electric fields to the inner magnetosphere, Fall AGU meeting, 2006. [accepted, refereed]

Kelley, M.C., V.K. Wong, M.J. Nicolls, A. Mannucci, and J. Chau, Calibration of COSMIC ionospheric profiles using incoherent scatter radars, Fall AGU meeting, 2006. [accepted, refereed]